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New records of dragonflies (Odonata) in Zambia

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Abstract

Zoogeographically important data on the occurrence of 22 dragonfly species in Zambia are presented, including at least seven species for the first time recorded or unambiguously confirmed in the country. They filled gaps in the previously known distribution ranges and showed that some of them reach further, especially to the south, but also west or north. Zoogeographical considerations are completed with some remarks on species' morphological traits and habitat selection and activity.

Keywords

Africa, Afrotropical fauna, zoogeography, Zygoptera, Anisoptera, Gynacanthini

Introduction

Studies of Afrotropical odonates have been significantly intensified since the end of the 20th century. Apart from many taxonomic works, they brought the spectacular event of publication on 60 new species for science (Dijkstra et al. 2015) and several syntheses, such as the first regional handbook for all Odonata from Sudan to Zimbabwe (Dijkstra and Clausnitzer 2014) and papers summing up present knowledge for Namibia (Suhling and Martens 2014), Botswana (Kipping 2010) and Angola (Kipping et al. 2017).

In contrast to adjacent countries, the published knowledge of odonate fauna of Zambia has still remained on a relatively low level. It is still mostly based on the synthetic paper from the 1980s (Pinhey 1984) with several later complements (e.g. Dijkstra 2007a, 2007b) and on the paper mentioned above (Dijkstra et al. 2015) intro-

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ducing new taxa. The presently known distribution of species in Zambia is illustrated on maps of the ADDO (African Dragonflies and Damselflies Online) website. These maps are based on and refer to the Odonata Database of Africa (ODA, see Kipping et al. 2009, Clausnitzer et al. 2012) and include many still unpublished data mostly obtained by Jens Kipping and colleagues from various expeditions to Zambia between 2007 and 2014. ODA currently contains 6,828 records of 260 Odonata species from Zambia and an updated checklist is in preparation (J. Kipping pers. comm.).

We organised three expeditions to central Zambia in various phases of the rainy season, in December 2013, April 2015 and January 2017. Apart from several localities visited on the way (in and near Kabwe), our studies were intentionally focused on a small remote area combining the bottom of the rift valley (the Luano Valley), its mountain slopes (the Muchinga Escarpment) and the adjacent upland plateau. In total, 107 species were recorded, but the whole material will be described in a separate paper analysing the species occurrence with reference to habitats in a small territorial scale. In the present paper, 22 selected species are presented, whose newly discovered localities are zoogeographically important to better explain the species distribution and to fill gaps or expand limits in the known pictures of ranges. Zoogeographical considerations are completed with some remarks on the morphological traits and habitat selection and activity of species.

Material and methods

All the investigated localities are situated in the Central Province of Zambia and almost all, apart from the last (No. 27 for *Trithemis nuptialis*), in broad environs of Chingombe, Luano District. Numbers of localities are given in square brackets.

Collected males are abbreviated to M and females to F. These individuals are in the collection of Rafał Bernard in the Nature Collections of the Faculty of Biology, Adam Mickiewicz University in Poznań, Poland.

An entry "1 M, 1 F" means that one male and one female were observed and collected. Another kind of entry, "3 ovipositing females (1 F)" means that three females were observed and one of them was collected.

Dimensions are given in millimetres. Abdominal length excludes appendages. The following abbreviations are used: Abd = abdominal length; S1–10 = abdominal segments 1–10; Fw = forewing; Hw = hindwing (when used with a number means hindwing length); Pt = pterostigma; Ax = antenodal cross-veins; Mx = median cross-veins; Al = anal loop cells; At = anal triangle cells; if the number of Ax, Mx, Al and At does not differ between the left and right wing of an individual, it is given as one number, (e.g. 31), but if it differs between wings of an individual, it is given for each wing in a pair separately, (e.g. 21/22). BMNH = The Natural History Museum, London, UK; MRAC = Musée royal de l'Afrique centrale, Tervuren, Belgium.

COI sequences of *Notogomphus* cf. *zernyi* and *Gynacantha* sp. were obtained with the use of standard procedures and compared with the known (partly unpublished) se-

quences from these genera in BOLD: the Barcode of Life Data System (Ratnasingham and Hebert 2007).

Data on the distribution of Odonata in Africa were taken from the Odonata Database of Africa (ODA) illustrated on maps of the ADDO website.

Localities

[1.] Dambo Kabufumu, 34.5 km WNW of the Chingombe catholic mission, by the road to Old Mkushi; 14°23.31'S, 29°38.96'E, 1,230 m a.s.l. – the plateau; a large (90×30 m) temporary pool in the dambo, i.e. in a river-like open valley, partly inundated with water in the wet season, between slopes with miombo woodlands. With crystal water up to 1 m deep and with abundant *Cyperus* sp., grasses and a large patch of *Persicaria senegalensis* f. *albotomentosa*.

[2.] Dambo Kabasa, 28.5 km WNW of the Chingombe catholic mission, by the road to Old Mkushi; 14°23.04'S, 29°42.23'E, 1,200 m a.s.l. – the plateau; a large (50×45 m) pool in the dambo. In 2015 and preceding years, highly astatic but probably semi-permanent. With rich and abundant vegetation: emergent grassy and *Schoenoplectus*-like along shores, nymphaeids *Nymphaea caerulea* on the water table and submerged *Ottelia ulvifolia*.

[3.] The Mikwa Stream, uppermost reach, just below a source, 8.3 km W of the Chingombe catholic mission; 14°25.27'S, 29°53.39'E (to 100 m upstream and downstream), 1,180 m a.s.l. – the mountains. Permanent, narrow (0.5–2 m), with heterogeneous morphology (boulders, cascades, strong-current sections and calm deeper stream pools) and correspondingly diverse bottom deposits from gravelly and sandy up to muddy with a thick layer of detritus. Locally with side seepages. Deeply shaded by a gallery forest, with small clearings.

[4.] The Mikwa Stream, upper reach, 8.0 km W of the Chingombe catholic mission; 14°25.15'S, 29°53.51'E, 1,160 m a.s.l. – the mountains. For the habitat description see [3.].

[5.] The Mikwa Stream, upper reach, 7.7 km W of the Chingombe catholic mission; 14°25.04'S, 29°53.67'E, 1,120 m a.s.l. – the mountains. For the habitat description see [3.]. Additionally, the main stream fed by a smaller watercourse and side trickles.

[6.] A small tributary of the Mikwa Stream, 7.5 km W of the Chingombe catholic mission; 14°25.03'S, 29°53.81'E, 1,110 m a.s.l. – the mountains. The narrow (0.3–0.6 m, exceptionally 1.5 m) headwater mountain stream: steep, with cascades and shelves, calmer and faster sections, sandy bottom, locally with detritus. Shaded with clearings.

[7.] A pool situated next to a small tributary of the Mikwa Stream, 7.5 km W of the Chingombe catholic mission; 14°25.03'S, 29°53.81'E, 1,110 m a.s.l. – the mountains. Small (1.8 m^2), temporarily fed by a trickle. With clear water (30–40 cm deep) and a lot of old leaves. Shaded with clearings.

[8.] Seepage feeding a tributary of the Mikwa Stream, 4.6 km W of the Chingombe catholic mission; 14°25.22'S, 29°55.40'E, 680 m a.s.l. – the mountains. Small (7 m^2), flowing from under a rock, with warm water and loose vegetation. Partly sunny.

[9.] The Mikwa Stream, lower reach, 4.6 km W of the Chingombe catholic mission; 14°25.23'S, 29°55.45'E, 670 m a.s.l. – the mountains. A few metres broad, with gravelly-stony bottom, boulders and rapids. Shaded by a gallery forest.

[10.] A pool 'hanging' in an earth-slip on the slope of the Mikwa Stream valley, 10 m above the stream, 4.2 km W of the Chingombe catholic mission; 14°25.17'S, 29°55.63'E, 640 m a.s.l. – the mountains. Small (4–5 m^2), deep (>1 m). Water not transparent, warm, fed by a warm-water trickle. Shaded with clearings.

[11.] A seepage trickle (feeding a small deep pool) on the slope of the Mikwa Stream valley, 10 m above the stream level, 4.2 km W of the Chingombe catholic mission; 14°25.17'S, 29°55.63'E, 640 m a.s.l. – the mountains.

[12.] A complex of a temporary pond, a narrow temporary stream feeding it and adjacent temporarily flooded grasslands, 0.6 km NNW of the Chingombe catholic mission, near a cemetery; 14°24.90'S, 29°57.80'E, 530 m a.s.l. – the bottom of the rift valley. The pond small (10×12 m), shallow in the beginning of the rainy season and even 1 m deep at the end of it; in 2013 partly and in 2015, totally densely overgrown by bamboos and other grassy and *Cyperus*-like vegetation.

[13.] Chingombe catholic mission, near a small power station; 14°25.07'S, 29°58.02'E (in the range of 100 m), 520 m a.s.l. – the bottom of the rift valley. Mosaic of open areas with single trees and loose banana plantations, mango woodlands and a dense wet forest patch. With a permanent concrete canal of the power station, an additional temporary shaded canal operating only during high water phases in the rainy season and a small pool in the forest.

[14.] A pool in the fields, 0.4 km SE of the Chingombe catholic mission; 14°25.32'S, 29°58.16'E, 510 m a.s.l. – the bottom of the rift valley. Small, bordered and partly overgrown with dense herbaceous and bushy vegetation.

[15.] The Chingombe River, a road ford 0.95 km ESE of the Chingombe catholic mission; 14°25.22'S, 29°58.51'E, 510 m a.s.l. – the bottom of the rift valley. An open, broadened (to 10–20 m), calm fragment of a small permanent fast clear-water river.

[16.] A pool on the Mulembwe (=Milembwe) temporary stream, 2.3 km NE of the Chingombe catholic mission; 14°24.45'S, 29°59.06'E, 530 m a.s.l. – the bottom of the rift valley. Small and shallow (to >0.5 m). Overgrown with abundant *Schoenoplectiella lacustris*, but in 2017, after the drought of 2016, only by grassy vegetation. Partly shaded, surrounded by miombo woodlands and grassy areas. As inhabited by very rare *Ceriagrion mourae* Pinhey, 1969, it was described and illustrated in Bernard et al. (2018).

[17.] A pool on the Mulembwe (=Milembwe) temporary stream, 0.2. km below the road, 2.4 km NE of the Chingombe catholic mission; 14°24.59'S, 29°59.20'E, 520 m a.s.l. – the bottom of the rift valley. Temporary, small (120 m^2), shallow (10–30 cm), with grassy vegetation.

[18.] A pool on the Mulembwe (=Milembwe) temporary stream, 0.4 km below the road, 2.5 km NE of the Chingombe catholic mission; 14°24.65'S, 29°59.30'E, 520 m a.s.l. – the bottom of the rift valley. Temporary, small (75 m^2), shallow, with grassy vegetation.

[19.] A pool in the light miombo woodland, 2.7 km NE of the Chingombe catholic mission; 14°24.37'S, 29°59.25'E, 520 m a.s.l. – the bottom of the rift valley. Temporary, small, shallow (to 50 cm), with an open water table bounded with herbaceous (mostly grassy) vegetation.

[20.] The Lukusashi River, 7.9 km SE of the Chingombe catholic mission; 14°27.52'S, 30°01.67'E (both river banks), 435 m a.s.l. – the bottom of the rift valley. Situated in hot open and semi-open landscapes, with bush and woodlands locally on the river banks. Fairly large: 40–200 m wide in the dry and wet season, respectively. Fairly fast flowing with variable water level: shallow and anastomosing within the broad river bed at the end of the dry season and swollen in the rainy season. Bottom deposits are mostly sandy, near banks more gravelly and, in lateral, calm or stagnant branches, sandy-muddy. In the low-water phase, almost without water vegetation, only with rare small patches of *Pistia stratiotes* and high grass 'walls' at the border of water and river banks. In the high-water period, with broadly flooded bank vegetation.

[21.] The Lukusashi River, 8.1 km E of the Chingombe catholic mission; 14°25.50'S, 30°02.51'E, 440 m a.s.l. – the bottom of the rift valley. For the habitat description see [20.].

[22.] Woodlands and a clearing by a ravine, 0.2–0.4 km of the Lukusashi River, 8.1 km E of the Chingombe catholic mission; 14°25.30'S, 30°02.49'E, 450 m a.s.l. – the bottom of the rift valley.

[23.] Two temporary pools (60 m distant) in a large meandering ravine, being a 'product' of temporary watercourse erosion, 150–200 m from the Lukusashi River, 8.1 km E of the Chingombe catholic mission; 14°25.38'S, 30°02.50'E, 450 m a.s.l. – the bottom of the rift valley. Situated in semi-open landscape, at the base of the ravine wall. Small, partly shaded by dense bushes with branches overhanging the water table. With soft clayey bottom and turbid shallow water.

[24.] The Bwingi Stream, 5.2 km NE of the Chingombe catholic mission; 14°23.14'S, 29°59.99'E, 510 m a.s.l. – the bottom of the rift valley. Complex of a permanent stream and its tributaries, seepages and temporarily flooded areas in its valley. The main stream mostly shaded with clearings and morphologically strongly diversified between 0.5–1 m wide shallow sections with moderate current and almost stagnant pools to 2 m wide and 1 m deep. In the stream bed, a mosaic of sandy-gravelly bottom and tree roots, abundant detritus and old leaves. The stream headwaters more open and more strongly flowing, with seepages.

[25.] Valley of the Bwingi Stream, 5.2 km NE of the Chingombe catholic mission; 14°23.13'S, 29°59.96'E, 510 m a.s.l. – the bottom of the rift valley. Grassy depressions, partly shaded by loose trees, situated in the fenny areas with seepages feeding the upper reach of the stream. At the very beginning of the rainy season

still dry, but may be flooded then as this is suggested by their structure and effects of first intensive rains.

[26.] The Kampoko River, a river ford on the road Chingombe-Mboroma, 26 km NE of the Chingombe catholic mission; 14°14.33'S, 30°07.23'E (to 300 m downstream), 490 m a.s.l. – the bottom of the rift valley. At the very beginning of the rainy season, a small river ranging from 1 m wide watercourse with side puddles up to 10–20 m wide calm sections; mostly shallow, with sandy, gravelly or stony bottom with boulders and some detritus deposits. Partly shaded with trees and bushes overhanging the water, but mostly open.

[27.] A tributary of the Mulungushi River near the Great North Road Kabwe-Kapiri Mposhi, 17.5 km NW of Kabwe; 14°19.10'S, 28°32.81'E, 1,125 m a.s.l. – the plateau. An open small very sluggish river with flooded valley (a few to 20 m wide). With thick soft bottom deposits and water up to 1 m deep, almost completely overgrown with dense herbaceous vegetation.

Results

Lestes ictericus Gerstäcker, 1869

[16.] 29 January 2017, emergence: 9 teneral individuals (3 M).
[19.] 21 April 2015, emergence: several individuals (2 M, 1 F); 29 January 2017, emergence: several individuals (1 M).

Very widespread in the Afrotropics, from Senegal and Sudan to South Africa, but known from a relatively low number of localities. Also in Zambia, previously known only from few records in the 1960s at the south-eastern border of the country, along the Zambezi River between Livingstone and Katambora Rapids (Pinhey 1984). Being to a large degree related to temporary standing waters, it occurs in grassy, reedy or sedge-lined shallow pans, ponds and rain-pools 'in dry bush country' especially in the savannah belt (Pinhey 1984, Tarboton and Tarboton 2015; see also the new localities). However, the recorded frequency of *L. ictericus* does not follow the abundance of such habitats: both Pinhey (1984) and Tarboton and Tarboton (2015) provided information about its local(ised) distribution and this fact was confirmed in the study area. Some unrecognised habitat requirements or simply low exploration level of these habitats might have been responsible for this inconsistency.

Allocnemis marshalli (Ris, 1921)

[3.] 26–28 January 2017, several individuals, mostly teneral/juvenile, but also adult (2 M: teneral and adult).
[4.] 28 April 2015, 2 adults (1 M).
[5.] 25 April 2015, 1 M, 1 F; 28 April 2015, 1 F.

[6.] 26 January 2017, 4 tandems (2 ovipositing) and 1 female (1 M and 1 F), mostly in the widest (1.5 m) and shallowest, partly sunny section, attracted by favourable oviposition conditions.
[8.] 20 January 2017, 2 males, 1 female (1 M, 1 F).
[11.] 19 January 2017, 1 F.

Widespread in a basin of the mountain Mikwa stream from its source to its lower reach, between 1,180 and 640 m a.s.l. Recorded at six localities, three related to the main stream and three to its tributaries. Occurred at side seepages and trickles and at the main beds of narrow and shallow streams. Teneral and juvenile individuals observed low on the herbaceous vegetation and bushes. Adults settled either quite high (two to several metres) on tree leaves or low in the direct neighbourhood of seepages and trickles. Especially on trees, selected small sunny spots in shady surrounds. Oviposition in submerged tree roots or thin rootlets in a very shallow current water of a small stream (Fig. 1); these favourable microhabitat conditions attracted three tandems in a short time. In the peak of the rainy season (the second half of January), the species occurred in all visited appropriate places and both the emergence and reproductive activity were recorded. At the very end of the rainy season (in late April), its occurrence was already limited to some places and its numbers were lower.

Recorded mostly in Zimbabwe, Mozambique and Malawi, with only one locality known in Katanga, DR Congo and one, raising doubts, in western Zambia (Fig. 10f) (Dijkstra 2018). The last site, the Sefula River in Barotseland (Pinhey 1984), might have been believed doubtful due to the plain nature of the area and the river that additionally does not flow through the forest, hence seems not to provide the necessary habitat conditions for the Afro-montane species of shaded forest. This inconsistency concerns not only coordinates given by Pinhey (1984) but also other sections of the river. However, as the exact location and habitat have remained unknown, there is no argument to finally reject the locality and it may be treated as not confirmed. In this unclear situation, the Mikwa stream basin appears the first doubtless location of a strong population of *A. marshalli* in Zambia (Fig. 10f).

Aciagrion africanum Martin, 1908

[1.] 20 December 2013, after first intensive rains but still without water, 3 M and 1 F.
[2.] 30 April 2015, emergence and reproductive activity: 1 tandem, 1 teneral male and 1 adult male (3 M, 1 F).

Mostly West and Central African species reaching south to Zambia and Malawi. In Zambia not rare, but previously known only in northern parts approximately to the latitude of Chingola and the Kasanka National Park (Pinhey 1984 and many unpublished records in ODA). The new localities extend the known species distribution range ca. 200 km southwards.

Figure 1. *Allocnemis marshalli* ovipositing in tree roots in a small mountain stream near Chingombe, Zambia (phot. B. Daraż).

Africallagma pallidulum Dijkstra, 2007

[1.] 20 December 2013, after first intensive rains but still without water, 2 M.
[12.] 16 December 2013, 1 F.
[25.] In moderate numbers in a very restricted area still without water: 9 December 2013, 2 M; 12 December 2013, 1 F; 17 December 2013, 3 M; 19 December 2013, 3 M, 2 F.

A quite recently described species, previously known only from uplands (1,150 m a.s.l. upwards) in a relatively narrow range between northern and central Zambia and Malawi (Dijkstra 2007b, 2018, unpublished records in ODA). Two of the new localities situated at lower elevations (510–530 m a.s.l.), at the bottom of the rift valley, at the southern border of the known species range. In the study area, related to temporary waters, rich in grassy and other herbaceous vegetation that correspond to the habitat spectrum given by Dijkstra (2007b, 2018). Already present at these sites when they are still dry, just before and after first intensive rains of the wet season.

Ceriagrion banditum Kipping & Dijkstra, 2015

[1.] 20 December 2013, after first intensive rains but still without water, 1 male, 1 tandem (2 M, 1 F); 31 January 2017, several individuals, 1 tandem (5 M, 2 F).
[2.] 30 April 2015, 1 teneral M.
[12.] 18 December 2013, 1 M.
[17.] 20 April 2015, 1 teneral M.

A recently described species, previously known from uplands (1,000 m a.s.l. upwards) in a relatively narrow range from northern Zambia through central and southern Malawi to northern Mozambique (Dijkstra et al. 2015, Dijkstra 2018). Four new localities showed fairly frequent occurrence also in central Zambia and not only in the upland plateau but also at lower elevations (520–530 m a.s.l.) at the bottom of the rift valley. In the study area, inhabited temporary or at least highly astatic water-bodies with abundant grassy and other herbaceous vegetation, but greater population numbers were recorded only in a large temporary clear-water pool in an upland dambo. The recorded habitat spectrum follows the preferences described by Dijkstra et al. (2015). Worth noticing is the early beginning of reproductive activity in the still dry breeding habitat, but after first intensive rains of the wet season.

Ceriagrion kordofanicum Ris, 1924

[20.] 8 December 2013, 3 males (2 M) in two small patches of floating *Pistia* in lateral river branches (but within the river bed), currently shallow and barely flowing or stagnant, but during the rainy season deeply flooded by the strong swollen river. The

species occurrence in such a river is noteworthy as the species is mostly associated with standing and often temporary waters, but also streams (Dijkstra 2018).

Mostly occurs in Eastern Africa, from South Sudan to Mozambique (Dijkstra 2018). In Zambia, previously known only from the north: very few data given by Pinhey (1984) and recent records from Sakufola nr. Ikelenge, Chimfunshi Wildlife Orphanage nr. Chingola and Shiwa N'gandu nr. Chinsali in November-December 2014 (J. Kipping coll., unpublished records in ODA). The new locality delineates the south-western border of the known species range.

***Pseudagrion commoniae* (Förster, 1902)**

[12.] 14 December 2013, 3 males above the water table of the pond (2 M).
[14.] 14 April 2015, 1 M.
[15.] 15 April 2015, fairly numerous, tandems (4 M 1 F), a male caught and consumed by male *Pseudagrion gamblesi* Pinhey, 1978.
[16.] 29 January 2017, 1 M (donated to the collection of Jens Kipping).
[18.] 21 April 2015, 1 teneral M.
[24.] 12 December 2013, 1 teneral M probably originating from the stream.
[26.] 17 December 2013, several males above the water table of wide and calm sections of the river (3 M).

An East African species occurring from Ethiopia to northern South Africa (Dijkstra 2018). In Zambia, previously known only from several localities at the southern border, from environs of Livingstone and the Musaya River (unpublished records in ODA, J. Kipping pers. comm.), with several records in the adjacent areas of Zimbabwe (Pinhey 1984). In the study area, not recorded in the mountains and the upland plateau and occurs only at the bottom of the rift valley where it is widespread and fairly common. The contrast between this relatively high frequency and small amounts of older Zambian data being localised only along the Zambezi River may be a result of the concentration of earlier Zambian studies in uplands while the species seems to prefer hot lower elevations. In the study area, occurs in both temporary and permanent waters, especially in broad and calm sections of watercourses and stream pools.

***Gynacantha vesiculata* Karsch, 1891**

[13.] 27 April 2015, 1 M foraging in a small meadow surrounded by trees, during the civil twilight phase.

Mostly recorded between 10° N and 10° S (Dijkstra 2018), reaching southwards to northern Zambia where previously known from four localities from the first half of

the 1960s, the southernmost being Chingola (Pinhey 1984), and a recent record from Sakeji School near Ikelenge (1 M, 25 November 2014, J. Kipping coll.). The new locality, situated ca. 300 km SE of Chingola, extends the known distribution range of the species to the south (Fig. 10b).

Gynacantha villosa Grünberg, 1902

[13.] 22 April 2015, 1 M; 26 April 2015, 1 F (Fig. 2). Both individuals foraged flying low above the ground or herbaceous vegetation in open places partly surrounded by trees, from sunset (17:49 h but with overcast sky) almost to the end of civil twilight (18:09 h).

The female (Fig. 2) identified on the basis of the combination of features: a) S3 constricted ('waisted') in 1/3–2/5 of its length; b) lateral carinae on S2 bent; c) cerci unmeasurable (broken and incomplete, Fig. 2a, b), but already in their basal part clearly broader than cerci in the compared *Gynacantha* sp., the shape of the existing fragments allows cerci to be assessed as leaf-like in contrast to stiletto-like cerci of the collected female of *Gynacantha* sp.; d) S9 only slightly longer than S8 (Fig. 2a, b, d); e) ventral carinae of S3–5 almost bare (only one denticle on S4 and three on S5); f) Hw: 51.1; g) dark T-mark on frons swollen, mushroom-like, with a broad elliptical stem with convex margins and with a thick and broadly spread 'mushroom cap' (Figs 2c, 3b). The last trait is not included in keys, but is similar in the collected male and female of *villosa* and different in the collected male of *G. vesiculata* (the stem quite broad, but triangular-deltoid and the upper arm (i.e. the cross-bar) less defined, blurred and flatter, Fig. 3a) and another in the collected female of *Gynacantha* sp. (the stem relatively narrower, weakly triangular-almost rectangular, with straight or weakly convex margins, Fig. 3c). This trait may be diagnostic as in some other species of *Gynacantha*, but requires confirmation in a larger sample. The listed combination of features suggests a typical form of *G. villosa*, also known from Katanga and excludes a misidentification of *G. vesiculata* (see Dijkstra 2005a).

One of most common large *Gynacantha*-species, mostly known from Eastern Africa and southern parts of Central Africa (Dijkstra 2018). In Zambia, previously recorded only from several localities in northern parts and at the southern border (Pinhey 1984, unpublished records in ODA).

Gynacantha sp. (from *africana*-group)

[13.] 15 April 2015, 1 F foraging at various heights, from above the herbaceous vegetation up to several metres, in an open place partly surrounded by trees (in the same place as *H. trinervulata* in the next days), just before 18:00 h, i.e. shortly after sunset (17:53 h), during the civil twilight phase.

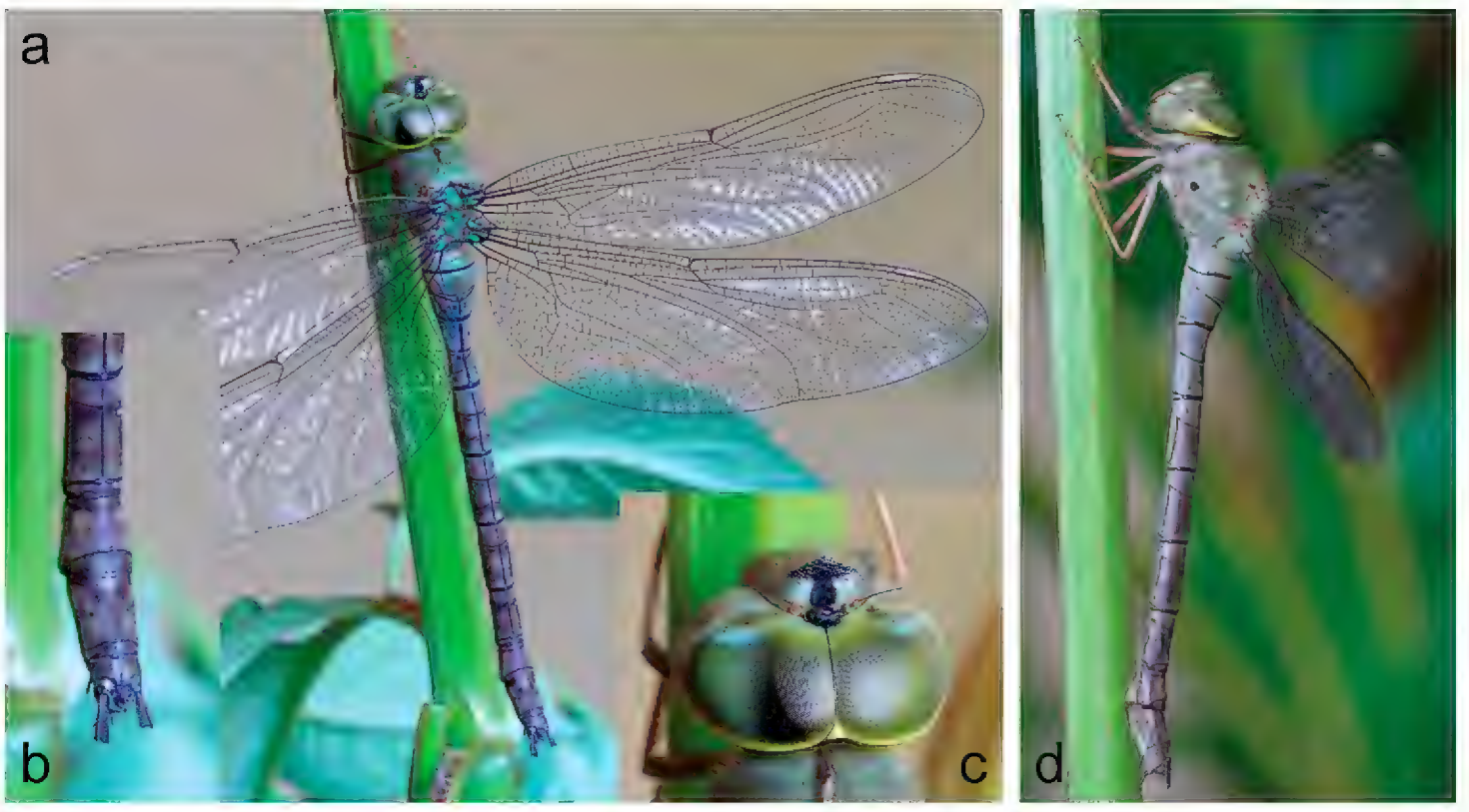

Figure 2. *Gynacantha villosa*, a female from Chingombe, Zambia: **a** a general dorsal view **b** distal segments of abdomen with remaining proximal parts of cerci **c** head with a T-mark on the frons **d** a general lateral view (phot. B. Daraż).

The collected female of *Gynacantha* sp. (Fig. 4) was compared with a female of *G. villosa* (Fig. 2), collected exactly at the same place. The following differences were noticed (*Gynacantha* sp. versus *G. villosa*): a) Hw: 54.0 versus 51.1; b) body: very robust versus clearly less robust; c) S3 almost cylindrical, only slightly narrowed in its proximal part versus constricted ('waisted') in 1/3–2/5 of its length; d) ventral carinae of S3–5 richly denticulate versus almost bare (only one denticle on S4 and three on S5); e) S9 about 1.5× as long as S8 (145–150%) (Fig. 4b, c) versus only slightly longer than S8 (Fig. 2a, b, d), this difference also being reflected in a striking contrast in size of the ovipositor; f) cerci narrow stiletto-like (6×0.6) (Fig. 4b, c) versus those of *villosa* unmeasurable (broken and incomplete), but at the same level in the proximal part clearly wider, so extrapolated as leaf-like (Fig. 2a, b); f) dark T-mark on frons relatively narrow and straight (Fig. 3c) versus more swollen, mushroom-like (Figs 2c, 3b), this difference being due to:

i. a quite thin weakly triangular-almost rectangular stem with straight or weakly convex margins (Fig. 3c) versus a relatively broader elliptical stem with convex margins (Figs 2c, 3b),
ii. a quite flat and rather short upper arm (cross-bar, Fig. 3c) versus a thicker and broadly spread 'mushroom cap' (Figs 2c, 3b).

The last trait is not included in keys, but its similarity in the collected male and female of *G. villosa* and different images in the collected female *Gynacantha* sp. and male *G. vesiculata* are worth noticing and checking on larger material.

The COI sequence of the studied female of *Gynacantha* sp., analysed in BOLD (The Barcode of Life Data System), is:

Figure 3. Frons in dorsal view, with a potentially diagnostic T-mark, of the individuals collected in Chingombe, Zambia: **a** male of *Gynacantha vesiculata* **b** female of *Gynacantha villosa* **c** female of *Gynacantha* sp. (phot. R. Bernard).

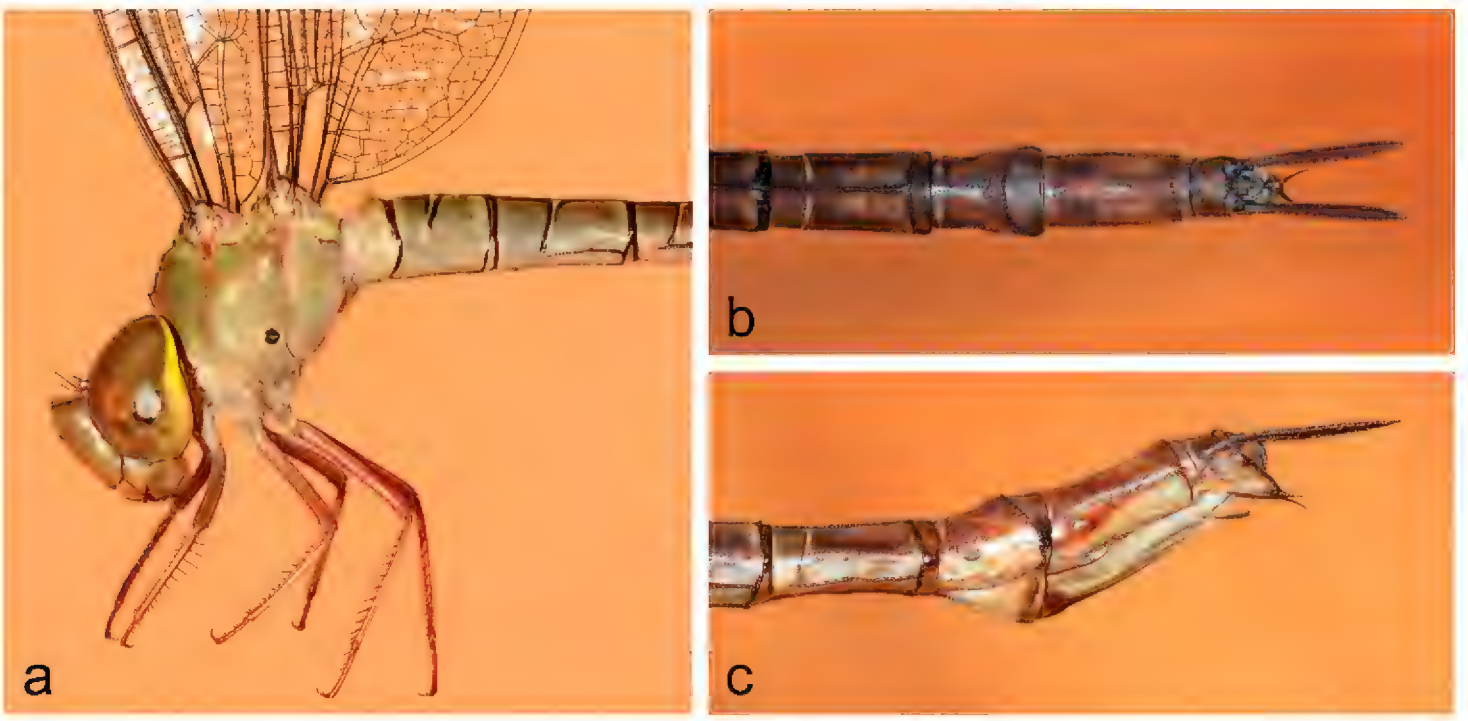

Figure 4. *Gynacantha* sp., a female from Chingombe, Zambia: **a** head, thorax and proximal segments of abdomen in lateral view **b** and **c** distal segments of abdomen with stiletto-like cerci in dorsal and lateral view (phot. B. Daraż).

i. very different from sequences of *Gynacantha cylindrata* and *G. vesiculata*;
ii. almost the same as an unpublished sequence of *Gynacantha villosa* from Tanzania (similarity 99.85%) and very close (99.26%) to a published sequence of *villosa* from coastal Kenya;
iii. clearly different (similarity 93.83 and 94.29%) from unpublished sequences of *Gynacantha villosa* from Ethiopia and Zambia.

These results and the BOLD TaxonID Neighbour-Joining Tree suggest that the name *Gynacantha villosa* comprises two different species and the studied female of *Gynacantha* sp. from central Zambia belongs to the taxon represented by the Tanzanian-Kenyan sequences. Already Dijkstra (2005a) has documented that coastal Tanzanian females of *villosa* are different from typical *villosa* as their S3 is almost cylindrical, cerci narrow and stiletto-like (6.5×0.6 mm), S9 almost twice as long as S8 and ventral carinae S3–5 denticulate. The collected female of *Gynacantha* sp. from central

Zambia has similar traits, so the second species within the present *Gynacantha villosa* may be recognisable, not only at a molecular level, but also in morphological features. However, all these molecular-morphological puzzles require further studies. Worth noticing is the sympatric occurrence of both species hidden under the name *villosa*, not only in larger scale, but even at the same locality: everything shows that we collected both these taxa, called in our article *Gynacantha villosa* and *Gynacantha* sp., in Chingombe, Zambia.

Gynacantha immaculifrons Fraser, 1956

[13.] 11 December 2013, 1 F; 10 April 2015, 1 M, 1 F; 23 April 2015, 1 M; all the individuals foraging in the same very small area of 400 m^2; on 10 April (sunset 17:57 h, end of civil twilight 18:18 h) the female appeared at 17:46 h flying very low in a deep shade under the mango tree while the male was collected at 18:00 h in a slightly lighter place but still under trees.

As only few individuals of the species were earlier known and analysed (Dijkstra 2005a), we showed the collected male and female (Fig. 5) and gave some measurable traits of Zambian specimens. Two males: Hw 43 and 47, FwAx 24/21 and 21/22, Al 9 and 10, At 3. Two females: Hw 48.5 and 49.5, FwAx 23/24, Al 10. All the diagnostic traits given by Dijkstra (2005a) and by Dijkstra and Clausnitzer (2014) occurred in Zambian males and females and differences, if found, were minute: S3 in two males were slightly more narrowed than in figures in literature, but not so narrowed as in other species and the genital fossa border of one male had 6 denticles on each side versus a diagnosed range 0–4 (in the second male 1 and 2).

A new species for Zambia. Previously known only from four localities, two in E Tanzania (Kichi Hills and Muheza District), one in N Malawi (Nkhata Bay) and one in Katanga (Lubumbashi) in DR Congo (Fraser 1956, Dijkstra 2005a, 2018, Clausnitzer 2006, unpublished records in ODA). The new locality, situated ca. 400 km SE of Lubumbashi and 560 km SW of Nkhata Bay, significantly extends the known distribution range of the species to the south (Fig. 10d). During the editorial process of our article, new data have been collected by Herb Kageler on Oldonyo Farm (17°14.27'S 29°35.94'E), near Tengwe, Hurungwe District, in northern Zimbabwe, showing that the species range reaches even further to 310 km to the south (Fig. 10d). The male and female photographed in Zimbabwe (17 and 18 September 2018) flew into the house in the morning (H. Kageler pers. comm.).

Heliaeschna fuliginosa Selys, 1883

[3.] 26 January 2017, 2 ovipositing females (1 F, Fig. 6); 28 January 2017, 3–4 ovipositing females (1 F). Appeared in the advanced afternoon, mostly between

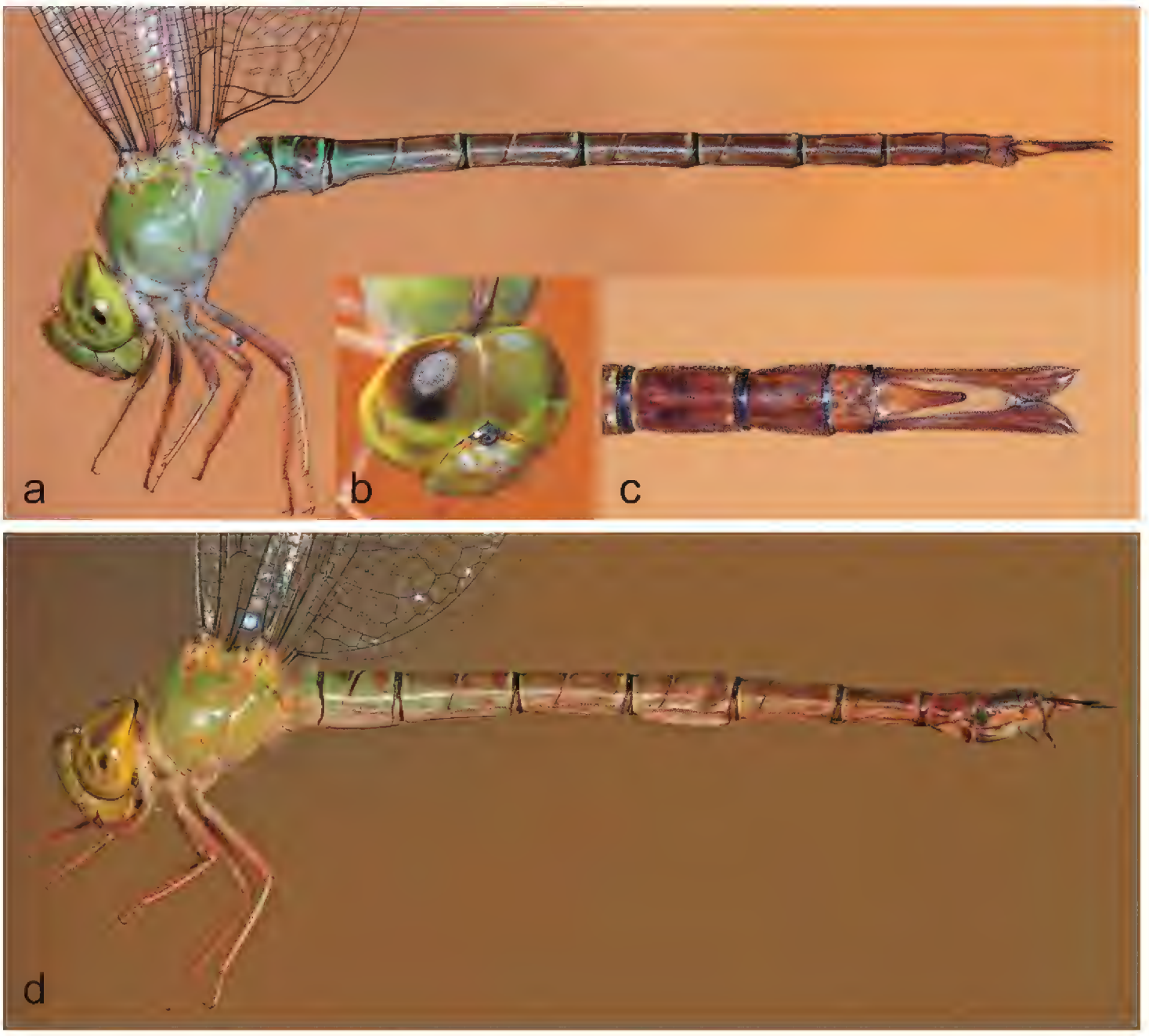

Figure 5. *Gynacantha immaculifrons* from Chingombe, Zambia: **a** male **b** head with a diagnostic almost unmarked postfrons **c** male appendages in dorsal view **d** female (phot. B. Daraż).

15:00–16:00 h (exceptionally earlier), only in good weather conditions (sunny, high temperatures). Occurred only at shaded short calm sections of the stream, without recognisable current and with detritus on the bottom. Especially concentrated at a stream pool with a very thick layer of soft deposits suffused with water and old leaves where females oviposited into submerged substrates at the shoreline. The microhabitat conditions closely resembled those described by Dijkstra (2018); however, the species occurred not in standing and temporary waters, but in permanent and flowing ones.

Two females: very large, Hw 54.2 and 55.3, FwAx 31 and 31/30, FwMx 6/7 and 5(and two halves)/7, HwMx 5 and 6. In one female FwMx 1–2 higher than HwMx in both wings, in the second female such a situation in one wing. HwAl 12/14 and 12/11. Measurable and countable data on female *fuliginosa* are scarce. However, Dijkstra (2005a) mentioned a large female (Hw 54) and ranges of vein numbers given by him for males also fully cover the Zambian females. The difference in Mx between

Figure 6. *Heliaeschna fuliginosa*, a female from the Mikwa Stream, near Chingombe, Zambia, with some recognisable diagnostic traits: the thoracic pattern, wing rays and wing venation (phot. B. Daraż).

Fw and Hw follows the tendency noticed in Central African males in contrast to West African ones (Dijkstra 2005a).

A new species for Zambia. Mostly recorded from Western and Central Africa, with only few records south of 5° S and two localities known from Katanga in DR Congo (Dijkstra 2018). The southernmost historic record from around Elisabethville (Lubumbashi) (1 M, no date available, Delfosse coll., MRAC, J. Kipping pers. comm.) was doubted because of a probable geographic inaccuracy. The new locality, situated ca. 400 km SE of Lubumbashi, significantly extends the known distribution range of the species to the south (Fig. 10a) and also shows the old Elizabethville record in a new light.

Heliaeschna trinervulata Fraser, 1955

[13.] 16 April 2015, 1 F; 18 April 2015 1 M; 23 April 2015 1 F; all the individuals juvenile, their condition suggested their emergence on the same day. Individuals observed just before a thunderstorm on 17 April 2015 and well before sunset on 27 April 2015 highly resembled those collected (size, colours, behaviour) probably also being *trinervulata*. All the individuals foraged at moderate to fairly great heights, from two to several metres, in open and semi-open places in a small area of several hundred square metres and were present 13–18 minutes before sunset (time of record/sunset): 17:40/17:53 h, 17:35/17:52 h, 17:31/17:49 h.

Due to juvenile condition, colouration of individuals is partly useless. However, all the substantial diagnostic traits, i.e.: a) size (Hw 35–37), b) details of relatively open venation (Fig. 7e), c) shape of rather narrow cerci and range of long epiproct (Fig. 7c, d), d) wing bases without dark subcostal rays but with distinct amber tint (prolonged distally in ante- and postnodal areas) in both females (Fig. 7e), e) relatively short pterostigma (Fig. 7a, e) and f) pale dorsum of frons with, at most, hint of a darker cross-bar (Fig. 7b, e), are consistent with species descriptions and figures (Fraser 1955, Pinhey 1966, Dijkstra 2005a, Dijkstra and Clausnitzer 2014).

The Zambian individuals were distinguished by lower numbers of cross-veins versus higher numbers given by Dijkstra (2005a) and Dijkstra and Clausnitzer (2014), i.e.: a) Mx: 2–3 versus 3–4, b) secondary Ax present proximal to proximal primary Ax: 0–1 versus 1–2 and c) Ax: 13–17 versus 15–19. This showed that, in the smallest individuals of the genus *Heliaeschna* (*H. trinervulata*), some traits of venation may be close to *Gynacantha* (see Dijkstra (2005a) and Dijkstra and Clausnitzer (2014)), so they should be checked in all wings and used together with other diagnostic features.

Due to poor and not always clear material, Dijkstra (2005a) considered *Heliaeschna trinervulata* and *Heliaeschna ugandica* McLachlan, 1896 as possible varieties of a single species, the latter being the large, dark, dense-veined extreme. The unambiguity and consistency of all diagnostic traits distinguishing *trinervulata* versus *ugandica* in all the three collected Zambian individuals is an argument for the distinct specific status of *trinervulata*.

Previously known only from upper Zambezi rapids in north-westernmost corner of Zambia (Pinhey 1984) and from several scattered localities in Uganda, N Tanzania, N Malawi and Katanga in DR Congo, with an uncertain occurrence in Central African Republic (Fraser 1955, Pinhey 1961, 1966, Dijkstra 2005a, 2018, unpublished records in ODA, J. Kipping pers. comm.). Not recorded since 1978 (Chinteche, Malawi: 1 M, 3 May 1978, M. Parr coll., BMNH; 1 M, 25 June 1978, R. Jocque coll, MRAC, J. Kipping pers. comm.). The new locality, situated ca. 730 km SE of the upper Zambezi rapids and 540 km SW of the Malawian Chinteche, significantly extends the known distribution range of the species to the south (Fig. 10c).

Figure 7. *Heliaeschna trinervulata* from Chingombe, Zambia: male (**a–d**) and female (**e**), with recognisable diagnostic morphological traits such as: relatively open venation (**a, e**) with a low number of cross-veins (e.g. Ax and Mx), the pale frons with a barely marked cross-bar of T-mark (**b, e**), wing bases without dark subcostal rays (**a, e**) but with distinct amber tint in the female (**e**) and shape of male cerci (**c, d**) (phot. B. Daraż).

Mastigogomphus cf. *dissimilis* (Cammaerts, 2004)

[21.] 15 December 2013, 1 exuviae near the bank in the transitional zone between the main flowing river branch and the side calm arm fed by seepages. Its diagnostic traits, i.e. the total length 36.5, the convex anterior border of prementum, the finger

like crenation of the labial palpus, proportions between the leg length and abdomen size, as well as between the tube (S10) length and the total length, were typical of the genus and almost exactly the same as illustrated by Suhling et al. (2014), but completely different than in *Neurogomphus*. However, the species was identified by presumption as the new locality was situated relatively close to the known range of *dissimilis* and far from known ranges of two other species of *Mastigogomphus* (Cammaerts 2004, Dijkstra 2018).

Historically, true *M. dissimilis* was known only from an area between 15° and 20° S, from three localities in S Malawi, E Zimbabwe and at the southern border of Zambia (*locus typicus* Katambora rapids of the Zambezi River) (Cammaerts 2004). A specimen from central Angola is currently the northernmost record (unpublished record in ODA, J. Kipping pers. comm.). Further records from four localities in the Caprivi in Namibia are treated as not fully confirmed due to only preimaginal stages found (Suhling et al. 2014, Suhling and Martens 2014, Dijkstra 2018). The new Zambian locality, if confirmed, would be the northernmost known locality in the eastern part of the species range (Fig. 10h).

***Notogomphus* cf. *zernyi* (St. Quentin, 1942)**

[9.] 7 December 2013, 1 teneral F (Hw 31, Abd 35.5, pt 3.5; Fig. 8) most probably belonging to that species.

The colour pattern already sufficiently developed to clearly assess the size and shape of pale and dark areas. The following features of this female (partly visible in Fig. 8) are typical of *N. zernyi* (see the original diagnosis by St. Quentin (1942), figures in Pinhey (1951), Dijkstra and Clausnitzer (2014), Dijkstra et al. (2015) and photographs on the ADDO website): a) an almost continuous pale dorsal line on S1–10; b) the pale lateral stripes on S1–10; c) the subgenital plate reaching ¼ of the S9 length; d) the tibiae with clear pale dorsal streaks; e) the pale costa; f) the dark interpleural stripe very narrow; g) the dark humeral stripe with a dorso-distal 'head' with a clear pale 'eye' in its middle; h) the pale antehumeral stripe significantly narrower than the preceding dark mesepisternal stripe and broadened dorso-distally into a small 'head'; i) the dark mesepisternal stripe up to 2× broader than the pale postdorsal stripe in the dorsal view and narrowed dorso-distally with an arched outer margin; j) the pale postdorsal stripes, separated from the pale middorsal carina and slightly bent outwards in their proximal parts; k) the pale face. This combination of traits does not occur in other known species of *Notogomphus*.

Several other features of the studied female may, however, raise some doubts about species identification. They are given below versus their different picture in Pinhey (1951), Dijkstra and Clausnitzer (2014) and Dijkstra et al. (2015): a) the dark interpleural stripe discontinuous, consisting of two short distant sections, near metastigma

and wing bases, versus a much longer stripe, continuous or almost continuous; b) a transverse stripe on mesokatepisternum through almost the whole breadth of it versus a shorter one forming only an upper 'tooth'; c) the vertex behind ocelli pale versus dark; d) the antefrons pale versus pale with the dark lower border. However, at least the a.–c. differences most probably reflect only an intraspecies variation as these features in the studied female are the same or similar to those in *N. zernyi* in photographs on the ADDO website. The breadth and shape of the pale postdorsal stripes also seem to show some intraspecies variation as: a) in the studied female and in Pinhey (1951), they are slightly narrower in relation to the mesepisternal stripe than in Dijkstra et al. (2015) and the photograph on the ADDO website; b) in the studied female, they are more cut and less round distally than in Pinhey (1951) and Dijkstra et al. (2015).

The middorsal area of the thorax appears the most problematic. In the studied female, the whole middorsal area along both the middorsal carina and a proximal section of the ante-alar ridge is pale; only the dorsal edge of the proximal ante-alar ridge is darkened (Fig. 8a–c). As a result, a clearly pale, slightly divided middorsal stripe occurs on the whole length of the middorsal area, the pattern slightly similar to that of *Notogomphus kimpavita* Dijkstra & Clausnitzer or *Notogomphus praetorius* (Selys). In contrast, the pale middorsal stripe in figures in Pinhey (1951) and Dijkstra et al. (2015) is short and restricted only to the proximal middorsal carina, while the distal part of the middorsal area is completely dark. At present, it is impossible to assess whether this difference has a diagnostic value suggesting a new species or it is only the next indication of intraspecies variation.

The COI sequence of the studied female, analysed in BOLD (The Barcode of Life Data System), appears quite close to known unpublished sequences of *Notogomphus zernyi*, with similarity 98.29%. The mean genetic distance between COI sequence groups recovered in the Neighbour-Joining analysis is 1.85% (SD=0.51) (the analysis due to K.D.-B. Dijkstra pers. comm.).

Considering the middorsal problematic feature, the not-completely matched species level by the molecular data and the tendency in this genus towards forming separate taxa in isolated areas, a new species of *Notogomphus* cannot be totally excluded. However, the vast majority of features, typical of the species or covered by the intraspecies variation, as well as the quite high similarity of COI sequences, suggest the female of *Notogomphus zernyi*. Therefore, we have decided to qualify it as cf. *zernyi*.

N. zernyi is known from E Zimbabwe, Malawi and SW Tanzania (Dijkstra 2018, unpublished records in ODA). Probably also recorded in north-eastern Zambia from Chowo (Cholo) Forest, Nyika Plateau, at the border with Malawi: two records were given by Pinhey (1966, 1979), but assigned to Malawi. In fact, the whole Chowo forest is located on the Zambian side of the Nyika Plateau, so possibly Pinhey's assignment was inaccurate and the Zambian origin of these data is quite probable (J. Kipping pers. comm.). The new locality is situated westwards of the previously known species range, 590 km SW of the localities in the Nyika Plateau and ca. 450 km NNW of the nearest locality in Zimbabwe (Fig. 10g).

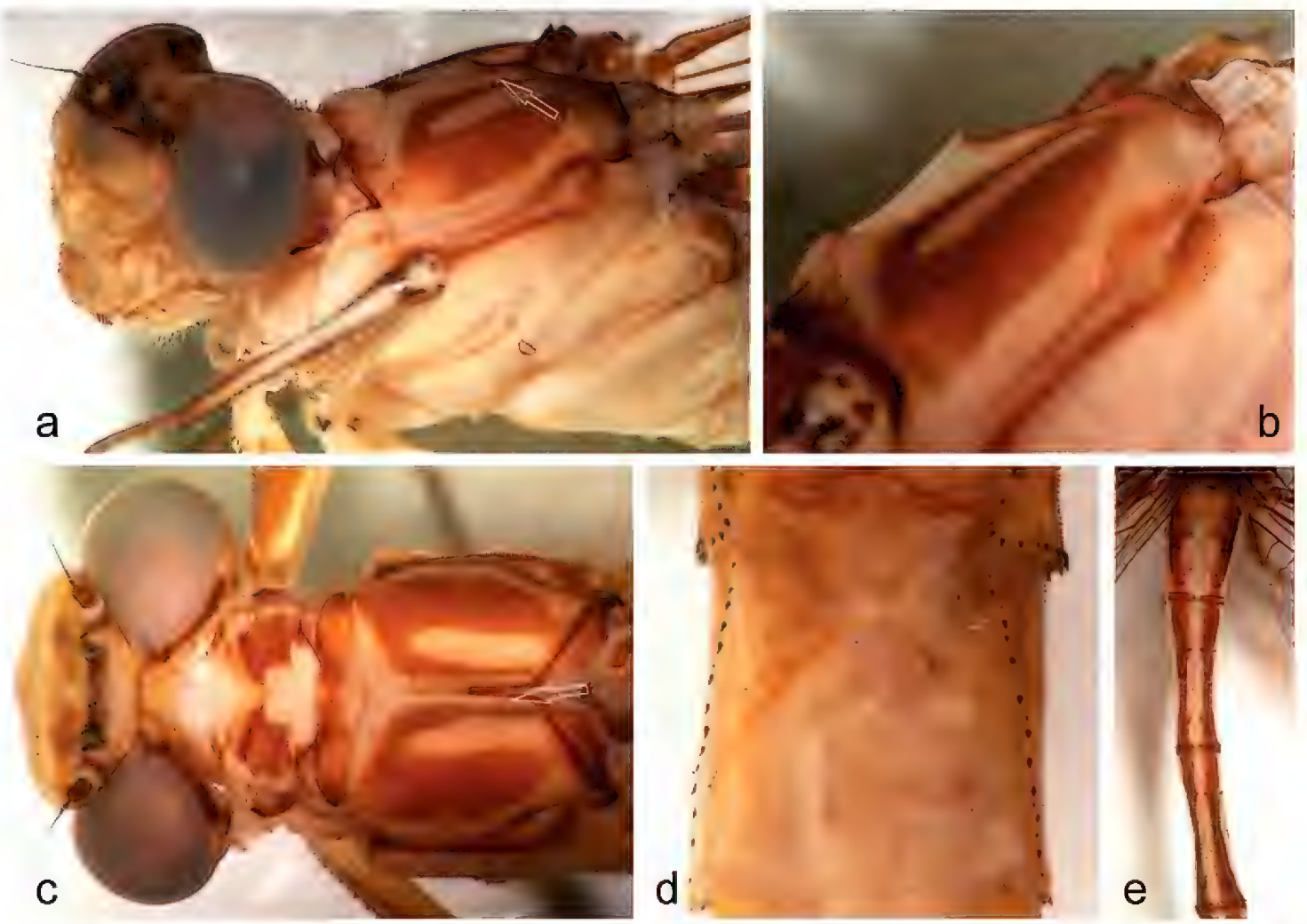

Figure 8. *Notogomphus* cf. *zernyi*, a teneral female from the Mikwa Stream, near Chingombe, Zambia, with details of the thoracic pattern in dorsal and lateral views (**a–c**), a subgenital plate (**d**) and the pattern of the proximal segments of abdomen in dorsal view (**e**); arrows indicate the pale distal part of the mid-dorsal stripe (phot. B. Daraż).

Phyllomacromia monoceros (Förster, 1906)

[3.] 26 January 2017, 3 males (2 M); 27 January 2017, 1 F; 28 January 2017, 1 M. Apart from a male intensively flying back and forth on the adjacent semi-open slope, all other individuals were observed above the water, mostly in shaded places where males flew rapidly.

In the collected males, an epiproct is only slightly shorter than cerci and all the males and the female are almost uniform in their dark and yellow pattern. A yellow spot in the frons groove and prejugal spots on S3–5 (on S5 small), separated by a black median line, point to an intermediate form (close to former *onerata*) between dark and pale extrema of the species (see Dijkstra 2005b).

Occurs in Eastern Africa, southwards reaching the northern parts of South Africa; its range also includes southern parts of Central Africa, i.e. Katanga and Zambia. In Zambia, previously known from several old records in the north-western 'corner' of the country around Ikelenge-Mwinilunga (Pinhey 1984). Recent unpublished records in ODA (J. Kipping pers. comm.) come from two localities in Central (1 F,

Kundalila Falls, 2 December 2014, J. Kipping coll.) and Northern Provinces (1 M, Mutinondo Wilderness, 13 December 2014, J. Kipping coll.), ca. 160–270 km NE of our new locality.

Notiothemis jonesi Ris, 1919

[3.] 27 January 2017, 3 territorial males and 1 tandem in copula (Fig. 9); 28 January 2017, 1 territorial male. Only at two short wider and calm sections of the stream (stream pools), one of them being its source.
[7.] 26 January 2017, 2 territorial males (1 M collected and immediately replaced with the second one).
[10.] 19 January 2017, 2 males: an aggressive resident and a visiting intruder (with a clash); 20 January 2017, 1 territorial M.

Relatively widespread in a basin of the Mikwa mountain stream, from its source to lower reach (1,180–640 m a.s.l.). Related to very small pools in the stream valleys and wider calm sections of streams in their headwaters. All the four places were: small (a few m^2), relatively deep (0.3–1 m), generally calm, but with some invisible flow or at least with water supply, permanent or at least semi-permanent, shaded with clearings, with tree branches overhanging at a height of several metres, with a layer of detritus and fallen leaves on the bottom, with sticks or stones emergent from the water or protruding from the shore and serving as roosting sites low above the water table. The male behaviour very consistent. Smaller pools 'housed' only one territorial male chasing away appearing intruders while, in the largest pool (a widened section of the stream), two residents occurred at a safe distance of 2.2 m. Although roosting sites were most frequently shaded, all the males appeared only in sunny weather and disappeared in cloudy times. Very shy: each movement in the surroundings was followed by their immediate, rapid and surprisingly unobtrusive vertical escape flight into the tree branches zone (see also Dijkstra and Clausnitzer 2014, Tarboton and Tarboton 2015) where they perched at a height of several metres. Returned after a few minutes or in the next sunny moment. Copulation on a stone in the stream bed within the male territory (Fig. 9).

A typical East African species, mostly occurring east of 30° E and ranging from Uganda and Kenya to South Africa (Dijkstra 2018). Previously, the nearest verified localities known in Zimbabwe (Pinhey 1984). The new discovery is the first confirmed occurrence of *N. jonesi* in Zambia (Fig. 10e). Shortly after our records, the species was also found by Bertie Brink in Katanga, DR Congo, close to the Zambian border (1 female, on the Kinsenda Mine Site, 12°15.89'S 27°57.23'E, 2 April 2017, B. Brink pers. comm.) and by Sara Elizalde in south-western Angola (1 male, Lubango, December 2017, J. Kipping pers. comm.) (Fig. 10e). The Angolan locality could have been interpreted as an exceptional outlier or, together with the new Zambian and Katangan data, as an indication that the species occurrence reaches much further west than expected before.

Figure 9. *Notiothemis jonesi*, copulation within the male territory in the bed of the Mikwa Stream near Chingombe, Zambia (phot. B. Daraż).

***Tetrathemis polleni* (Selys, 1869)**

[23.] 21 January 2017, 3 territorial males (2 M) on overhanging dry bush branches and on sticks 0.5–2.5 m above the water table of pools. One of them also with a female in copula; the copulation wheel was formed in flight and the pair in this position flew down between overhanging bush branches. Temporary nature of the pools, their location in a ravine and presence of overhanging branches and soft bottom highly resemble the habitat description given by Dijkstra (2018).

A new species for Zambia although two nearest known localities are situated in Zimbabwe just at the border with Zambia (Pinhey 1984, unpublished records in ODA, J. Kipping pers. comm.). Widespread in Eastern Africa and also known from some localities in western parts of the continent (Dijkstra 2018).

***Tramea limbata* (Desjardins, 1832)**

[1.] 31 January 2017, 1 male patrolling large areas above the water table at a distance from the shores and 1 tandem: not collected but undoubtedly identified.
[2.] 30 April 2015, 1 male persistently patrolling above the water table, at a distance from the shores (1 M).

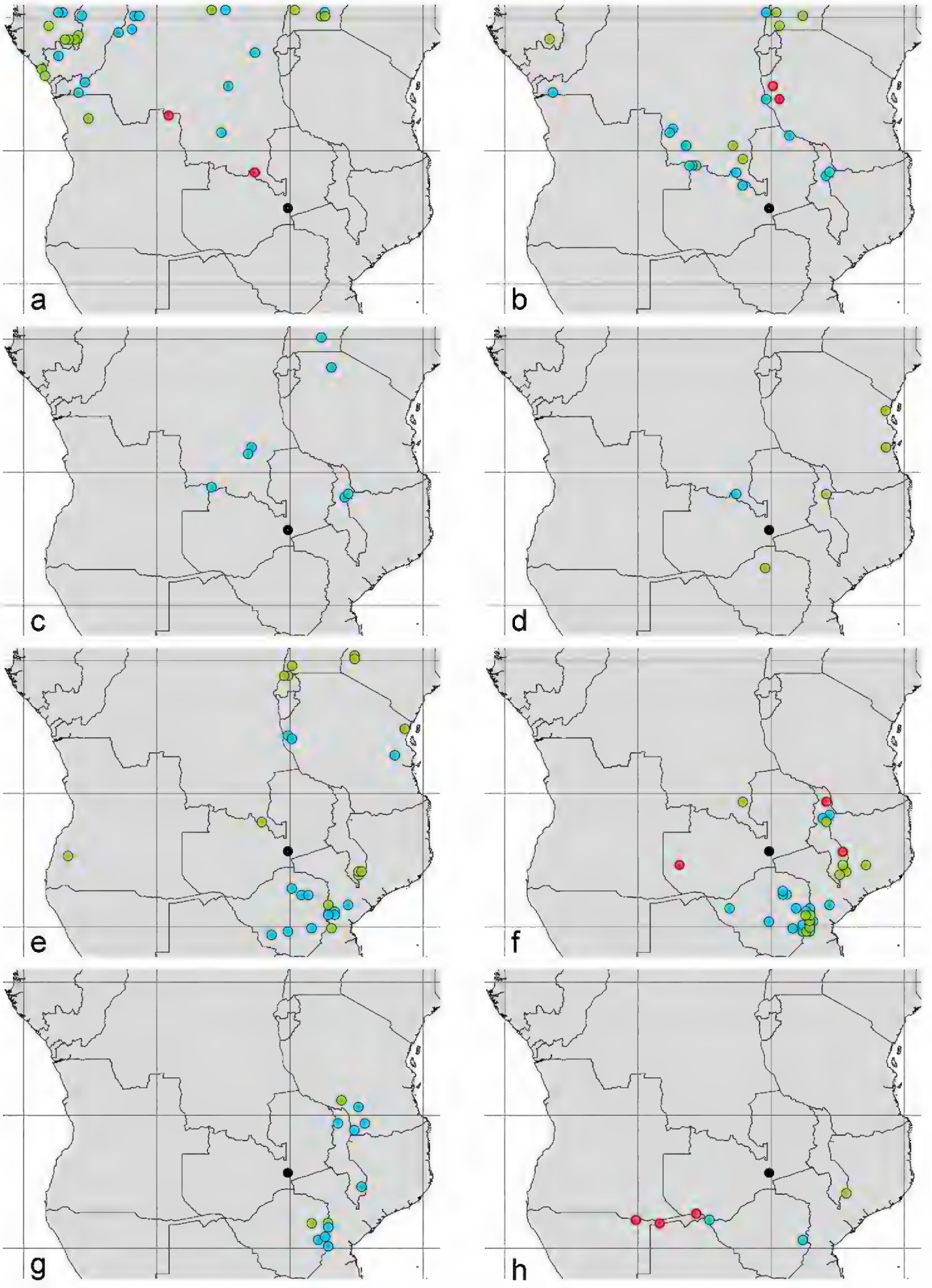

Figure 10. Distribution of selected dragonfly species in the southern Afrotropics (between the Equator and the southern border of Zimbabwe): **a** *Heliaeschna fuliginosa* **b** *Gynacantha vesiculata* **c** *Heliaeschna trinervulata* **d** *Gynacantha immaculifrons* **e** *Notiothemis jonesi* **f** *Allocnemis marshalli* **g** *Notogomphus zernyi* **h** *Mastigogomphus dissimilis*. The black dot – the new locality. Other points – other data according to literature and Odonata Database of Africa (J. Kipping pers. comm., Clausnitzer et al. 2012) and recent unpublished data (B. Brink and H. Kageler pers. comm.), mostly drawn from the ADDO (African Dragonflies and Damselflies Online) website: blue – pre-1990 records; green – vetted since-1990 records; red – identification and/or locality uncertain.

The species with a giant Afro-Asian distribution range, widespread in the Afrotropics and locally common, e.g. in parts of South Africa, but surprisingly rarely recorded in Central Africa (Dijkstra 2018). New for Zambia, with the nearest previous record in the Caprivi, Namibia (Suhling and Martens 2014).

Trithemis donaldsoni (Calvert, 1899)

[26.] 17 December 2013, 3 M in sunny places with stones and boulders at broader, both calm and more flowing sections of the river.

An East and South African species (Dijkstra 2018), in Zambia previously known only from three unpublished records in the south, along the Zambezi and Musaya Rivers (ODA, J. Kipping pers. comm.), with several localities in the adjacent areas of Zimbabwe (Pinhey 1984).

Trithemis nuptialis Karsch, 1894

[27.] 13 January 2017, several males and 1 tandem (2 M).

Occurs mainly in Central Africa (Dijkstra 2018). In Zambia, previously recorded at several localities in the northern parts of the country (Pinhey 1984). More recent records reach areas south of Ndola (Nsobe Game Camp, February 2010, J. Kipping coll., unpublished records in ODA). The new locality, situated a further 100 km southwards, is the southernmost known locality of the species.

Trithemis werneri Ris, 1912

[22.] 21 January 2017, several males (3 M, two immature); 24 January 2017, in moderate numbers, dispersed at several sites. Perched in sunny places on bushes and especially on tips of sticks above the herbaceous vegetation in woodlands and at clearing edges. Certainly associated with the Lukusashi River (the locality [21.]), but absent from the bank vegetation and direct neighbourhood of the swollen river. Such a situation, noticed as often occurring in this species (Pinhey 1984), probably reflects the non-breeding phase of imaginal life, starting relatively late in the rainy season, from January (Tarboton and Tarboton 2015).

A largely East African species penetrating here and there into central and southwestern parts of the continent (Dijkstra 2018). In Zambia, previously known only from two unpublished records east of Chirundu Bridge on the country's southern border (many individuals, the Zambezi River in environs of Wildtracks Lodge, February 2007, J. Kipping coll., unpublished records in ODA). Also recorded from Chirundu Bridge in Zimbabwe by Pinhey (1984).

Discussion

Our studies revealed that distribution ranges of several species, such as *Aciagrion africanum*, *Gynacantha vesiculata*, *G. immaculifrons*, *Heliaeschna fuliginosa*, *H. trinervulata* and *Trithemis nuptialis*, reach further south that was previously known (Fig. 10a–d). This suggests that rich Afrotropical odonate fauna, known from central and eastern Africa to Katanga and northern Zambia, also partly occur in central Zambia, in the Zambezi River Basin. This is true especially for species associated with temporary waters and permanent watercourses; scarcity of permanent standing waters is a limiting factor for many other species in this area. Central Zambia also turned out to be penetrated by typically eastern fauna, known from Tanzania, Mozambique, Malawi, Zimbabwe and adjacent parts of the Katanga Province of DRC, for example, by *Gynacantha immaculifrons*, *Allocnemis marshalli*, *Notiothemis jonesi*, most probably *Notogomphus zernyi* (Fig. 10d–g) and also found by us, but described in another paper *Ceriagrion mourae* (Bernard et al. 2018). This interesting zoogeographical mosaic is completed by: a) two recently described species, limited to a narrow latitudinal stripe including parts of Zambia and adjacent Malawi and Mozambique (*Ceriagrion banditum* and *Africallagma pallidulum*) and b) also narrowly but more southerly distributed *Mastigogomphus dissimilis* (Fig. 10h).

The evening concentration of five species of Gynacanthini in a small area near the power station in the Chingombe mission showed especially favourable conditions existed there, at least for foraging activity. Although larval habitats were not found, the flight of *Gynacantha immaculifrons* in subsequent years exactly under the same tree, as well as the presence of juvenile *Heliaeschna trinervulata*, suggested the native occurrence somewhere nearby, possibly in an adjacent patch of very dense wet forest and bush. This concentration occurred at the end of the rainy season, but, in the peak of it (in January), imagines of Gynacanthini were not recorded there despite special searches. Both of these facts, as well as colours and state of collected imagines, suggested that this concentration was related to the immature phase of life.

Crepuscular activity was typical of all the five species of Gynacanthini recorded in the mission. However, the measured data and several unmeasured but localisable-in-time situations showed a sequence of species. *Heliaeschna trinervulata* appeared as the first, still in quite good light conditions, beginning from the latest sunshine. In contrast to Pinhey's observations from Malawi (1966), it was not recorded at dusk. It was flying in more open, unshaded conditions at moderate to fairly great heights similar to those given by Pinhey (1966). The next recorded species – *Gynacantha immaculifrons* – was observed from 11 minutes before sunset to the first minutes after it (to early twilight), however, two early individuals additionally selected places in deep shade. *Gynacantha vesiculata*, *Gynacantha villosa* and *Gynacantha* sp. appeared late. All were active in open and semi-open places in weakening light after sunset, in the phase of civil twilight. The earliest individual (*villosa*) appeared just at the time of sunset but in dark cloudy conditions while the last one (*villosa*) was hardly detectable flying extremely low at civil dusk.

Although precise data on habitat selection by gynacathines are generally scarce, species of *Heliaeschna* are perhaps associated with more permanent water than *Gynacantha*, like swamp forest or streams (Dijkstra 2005a). This presumption found some confirmation in our study area, in the occurrence of *Heliaeschna fuliginosa* in headwaters of a permanent mountain stream. Females oviposited there into submerged substrates at the shoreline clearly selecting calm stream pools, rich in soft detritus and leaves and omitting narrow strong current sections. The selected sites of mixed lentic and lotic nature provided not only calm conditions with good oxygenation, but also excellent microhabitats for larvae. This situation corresponds to the data from the Liberian rainforest stream from which Lempert (1988) reported *H. fuliginosa*, both its larva and adults of both sexes flying along the stream. However, Neville (1960) saw oviposition of *H. lanceolata* (= *fuliginosa*) in different conditions, i.e. in "moist soil around the ponds", so in the habitat more typical of *Gynacantha* (Dijkstra 2005a). Neville's report was different from our data in one more aspect: he observed individuals "hawking over ponds all through the day until after dusk" and still heard them "when darkness fell", but he did not provide information about the weather conditions. In our studies, the presence of *H. fuliginosa* at the Mikwa stream was restricted to sunny and hot afternoons, especially to their later phase between 15:00 h and 16:00 h. We did not observe the species at the stream in the morning and in the evening and during overcast weather. Despite selecting shaded places, the females clearly preferred the hottest day phases with afternoon sunlight.

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References

Bernard R, Daraż B, Dabert M (2018) Redescription of *Ceriagrion mourae* with notes on its position in the genus *Ceriagrion* (Odonata: Coenagrionidae). International Journal of Odonatology 21(2): 151–163. https://doi.org/10.1080/13887890.2018.1464524

Cammaerts R (2004) Taxonomic studies on African Gomphidae (Odonata, Anisoptera). 2. A revision of the genus *Neurogomphus* Karsch, with the description of some larvae. Belgian Journal of Entomology 6: 91–239.

Clausnitzer V (2006) Dragonflies (Odonata) of Rufiji District, Tanzania with new records for Tanzania. Journal of East African Natural History 95(2): 139–162. https://doi.org/10.2982/0012-8317(2006)95[139:DOORDT]2.0.CO;2

Clausnitzer V, Dijkstra K-DB, Koch R, Boudot J-P, Darwall WRT, Kipping J, Samraoui B, Samways MJ, Simaika JP, Suhling F (2012) Focus on African freshwaters: Hotspots of dragonfly diversity and conservation concern. Frontiers in Ecology and the Environment 10(3): 129–134. https://doi.org/10.1890/110247

Dijkstra K-DB (2005a) Taxonomy and identification of the continental African *Gynacantha* and *Heliaeschna* species (Odonata: Aeshnidae). International Journal of Odonatology 8(1): 1–32. https://doi.org/10.1080/13887890.2005.9748240

Dijkstra K-DB (2005b) The identity of some widespread and variable *Phyllomacromia* species, with a revised grouping of the genus (Anisoptera: Corduliidae). Odonatologica 34: 11–26.

Dijkstra K-DB (2007a) The name-bearing types of Odonata held in the Natural History Museum of Zimbabwe, with systematic notes on Afrotropical taxa. Part 1: Introduction and Anisoptera. International Journal of Odonatology 10(1): 1–29. https://doi.org/10.1080/13887890.2007.9748285

Dijkstra K-DB (2007b) The name-bearing types of Odonata held in the Natural History Museum of Zimbabwe, with systematic notes on Afrotropical taxa. Part 2: Zygoptera and descriptions of new species. International Journal of Odonatology 10(2): 137–170. https://doi.org/10.1080/13887890.2007.9748296

Dijkstra K-DB (2018) African Dragonflies and Damselflies Online. http://addo.adu.org.za/

Dijkstra K-DB, Clausnitzer V (2014) The Dragonflies and damselflies of Eastern Africa: Handbook for all Odonata from Sudan to Zimbabwe. Studies in Afrotropical Zoology 298. Royal Museum for Central Africa, Tervuren, 263 pp.

Dijkstra K-DB, Kipping J, Mézière N (2015) Sixty new dragonfly and damselfly species from Africa (Odonata). Odonatologica 44: 447–678. https://doi.org/10.5281/zenodo.35388

Fraser FC (1955) Odonata. Exploration du Parc National de l'Upemba. Mission G. F. de Witte, en collaboration avec W. Adam, A. Janssens, L. van Meel et R. Verheyen (1946–1949) 38(1): 1–34.

Fraser FC (1956) *Pseudagrion superbum*, *Gynacantha flavipes* and *Gynacantha immaculifrons*, three new species of Odonata from the Belgian Congo. Revue de Zoologie et de Botanique Africaines 54: 382–387.

Kipping J (2010) The dragonflies and damselflies of Botswana – an annotated checklist with notes on distribution, phenology, habitats and Red List status of the species (Insecta: Odonata). Mauritiana (Altenburg) 21: 126–204.

Kipping J, Dijkstra K-DB, Clausnitzer V, Suhling F, Schütte K (2009) Odonata Database of Africa (ODA). Agrion 13: 20–23.

Kipping J, Clausnitzer V, Fernandes Elizalde SRF, Dijkstra K-DB (2017) The dragonflies and damselflies (Odonata) of Angola. African Invertebrates 58(1): 65–91. https://doi.org/10.3897/AfrInvertebr.58.11382

Lempert J (1988) Untersuchungen zur Fauna, Ökologie und zum Fortpflanzungsverhalten von Libellen (Odonata) an Gewässern des tropischen Regenwaldes in Liberia, Westafrika. Diplomarbeit, Friedrich-Wilhelms Universität, Bonn.

Neville AC (1960) A list of Odonata from Ghana, with notes on their mating, flight and resting sites. Proceedings of the Royal Entomological Society of London 35(7–9): 124–128. https://doi.org/10.1111/j.1365-3032.1960.tb00680.x

Pinhey ECG (1951) The Dragonflies of Southern Africa. Transvaal Museum Memoirs 5. Transvaal Museum, Pretoria, 335 pp.

Pinhey E (1961) A survey of the dragonflies (order Odonata) of Eastern Africa. British Museum (Natural History), London.

Pinhey E (1966) Check-list of dragonflies (Odonata) from Malawi, with description of a new *Teinobasis* Kirby. Arnoldia (Rhodesia) 2(33): 1–24.

Pinhey E (1979) Additions and corrections to the 1966 checklist of dragonflies (Odonata) from Malawi. Arnoldia (Rhodesia) 8(38): 1–14.

Pinhey E (1984) A checklist of the Odonata of Zimbabwe and Zambia. Smithersia 3: 1–64.

Ratnasingham S, Hebert PDN (2007) BOLD: The Barcode of Life Data System (www.barcodinglife.org). Molecular Ecology Notes 7(3): 355–364. https://doi.org/10.1111/j.1471-8286.2007.01678.x

Suhling F, Martens A (2014) Distribution maps and checklist of Namibian Odonata. Libellula (Supplement 13): 107–175.

Suhling F, Müller O, Martens A (2014) The dragonfly larvae of Namibia (Odonata). Libellula (Supplement 13): 5–106.

Tarboton W, Tarboton M (2015) A guide to the dragonflies & damselflies of South Africa. Struik Nature, Penguin Random House South Africa, Cape Town.